

Light Travel Times

NASA satellites and space probes are so far away from Earth that serious time delays happen when radio signals are sent to them. This is because radio signals travel at the speed of light, 300,000 kilometers/sec, and the distances from Earth to the spacecraft are huge!!

Spacecraft	Distance (km)	Seconds	Minutes	Hours
Themis P2	30,000			
LRO	382,000			
ACE	1.5 million			
MESSENGER	50 million			
STEREO-A	111 million			
Mars Orbiter	220 million			
Ulysses	800 million			
Cassini	1.8 billion			
Voyager 2	13 billion			



This image was taken by the Hubble Space Telescope and shows the satellite Io (Courtesy J. Spenser, Lowell Observatory and NASA). The moon is the small disk to the left, and its shadow appears to the right of center.

Problem 1 - How long will it take for a radio signal to travel from the satellites to Earth, one-way, in the above table? Complete the last three columns to find out!

Problem 2 - Suppose a radio message needs to be sent at 01:20 on February 15, 2008. To the nearest minute, what time would it be when the message arrived at each spacecraft, and when the data arrived back at Earth?

Problem 3 - When Jupiter was located farthest from the sun (Aphelion), it was at a distance of 667 million kilometers from Earth. When it was closest to the sun (perihelion) it was 590.5 million kilometers from Earth. Suppose you are calculating a schedule for when the satellite Io will be exactly at dead-center of Jupiter's disk based on when you saw the transit at Perihelion. How much of a schedule change will you see when you observe the transit at aphelion, and will the transit occur sooner or later than you predicted?

Answer Key

Problem 1 – Answer:

Spacecraft	Distance (km)	Seconds	Minutes	Hours
Themis P2	30,000	0.1	0.0017	0.00003
LRO	382,000	1.3	0.021	0.00035
ACE	1.5 million	5.0	0.083	0.0014
MESSENGER	50 million	167	2.8	0.046
STEREO-A	111 million	370	6.2	0.10
Mars Orbiter	220 million	733	12.2	0.20
Ulysses	800 million	2,667	44.4	0.74
Cassini	1.8 billion	6,000	100.0	1.7
Voyager 2	13 billion	43,333	722.2	12.0

Problem 2 - Answer: see table below:

Spacecraft	Distance (km)	Arrival at satellite	Arrival at Earth	One-way time
Themis P2	30,000	01:20	01:20	0.2 sec
LRO	382,000	01:20	01:20	2.6 sec
ACE	1.5 million	01:20	01:20	10 sec
MESSENGER	50 million	01:23	01:26	2.8 minutes
STEREO-A	111 million	01:26	01:32	6.2 minutes
Mars Orbiter	220 million	01:32	01:44	12.2 minutes
Ulysses	800 million	02:04	02:49	44.4 minutes
Cassini	1.8 billion	03:00	04:44	1.7 hours
Voyager 2	13 billion	13:20	01:20 Feb 16th	12.0 hours

Problem 3 - When Jupiter was located farthest from the sun (Aphelion), it was at a distance of 667 million kilometers from Earth. When it was closest to the sun (perihelion) it was 590.5 million kilometers from Earth. Suppose you are calculating a schedule for when the satellite Io will be exactly at dead-center of Jupiter's disk based on when you saw the transit at Perihelion. How much of a schedule change will you see when you observe the transit at aphelion, and will the transit occur sooner or later than you predicted?

Answer: The difference between Jupiter's distance in each case is $667 \text{ million} - 590.5 \text{ million} = 76.5 \text{ million kilometers}$. At the speed of light, this equals a time difference of $76500000/300000 = 255 \text{ seconds}$ or 4.25 minutes . At the time the transit occurs at aphelion, the event will be seen about 4.25 minutes later than the predicted time.